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ABSTRACT

In the first part of this paper, the purposes of behavioral objectives are outlined; research is then summarized, including the influence of knowledge of the behavioral objectives on a learner's performance, teacher recognition of behavioral objectives, and student attitudes to behavioral objectives. The second part presents a summary of methods of constructing learning hierarchies. The research topics outlined include the structure and efficiency of expert versus student generated hierarchies, relationships between performances on adjacent levels of a hierarchy, and the psychometrics of learning hierarchies. Each part of this paper contains a table of the research hypotheses investigated, with a listing of supporting and non-supporting experiments reported. Although most of the research reviewed refers to mathematics and science, studies in other areas are also included. (MM)

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MATHEMATICS EDUCATION REPORTS

A REVIEW OF RESEARCH ON BEHAVIORAL OBJECTIVES AND LEARNING HIERARCHIES

by

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and

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ERIC Information Analysis Center for
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This paper reviews recent research on behavioral objectives and on learning hierarchies. The paper was commissioned by ERIC/SMEAC because of interest in these areas by science and mathematics educators. Although the majority of research reviewed refers specifically to mathematics and science learning, the review does include studies done in other subject areas.

A unique feature of this review is the tabulation of research into supporting and non-supporting categories arranged by general research hypotheses. When these tables (pp. 19-20 and pp. 57-61) are used in conjunction with the paper's extensive bibliography, the reader can structure research in these areas very quickly.

Jon L. Higgins
Editor

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Researchers pursue the investigation of phenomena by examining relationships among two or more variables. But productive researchers appear not to blindly select variables on which to collect data, rather they select variables that hold the promise of explaining some particular phenomena under investigation. Often, in the behavioral sciences, variables are sampled because they may account for all or part of a source of observed variance. Investigations of behavioral objectives and learning hierarchies has been an area of intense research activity in recent years. Much of this research has focused upon the observed variance in acquisition, rate of acquisition, forgetting and rate of forgetting among learners. The following narrative is a review of this literature.

The review is separated into two sections. The first section reports the literature on behavioral objectives. The second section describes the literature on learning hierarchies.

Section One
Behavioral Objectives

The behavioral objectives review identifies the research literature, attempts to organize the investigations into research themes, and summarizes the current level of knowledge for each of the themes named. The morality of behavioral objectives as good or bad for instruction, or curriculum development, or evaluation is not considered a purpose for this review. Rather, it is argued that the best service to the educational research community is rendered by examining the literature for those instances where behavioral objectives have been used as an independent or dependent variable; and avoid entering into still another polemic about behavioral objectives. The search attempted to locate researchable conjectures as well as identifying results from reported investigations.

Positions About Behavioral Objectives

Much of the literature on behavioral objectives does not concern itself with research -- even under a most generous interpretation of what constitutes research. These expositions resemble a sequence of antieirenics. In commenting on the current intensity of the behavioral objectives dialog Eisner (1) observed, " - - - the statement 'Educational objectives should be stated in behavioral terms' has been elevated -- or lowered -- to almost slogan status - - -."

Proponents of behavioral objectives such as Gagne (2), Glaser (3), Kurtz (4), Lindvall (5), Mager (6), Popham (7), Tyler (8), and Walbesser (9) usually cite the advantages of having a student and teacher know where they are going and how to evaluate their progress. Opponents of behavioral objectives such as Arnstine (10), Atkin (11), May (12), MacDonald (13), and Raths (14) usually argue that precise objectives may hinder the full development of the student or force the teacher and student into an inflexible instructional mode. There is little evidence that any constructive interchange between these positions has yet occurred. The nature of definitive experiments that might resolve one or more of the differences between these positions have not been proposed; and from the standpoint that these are value positions, resolution on an empirical basis may not ever be possible.

The Association of Behavioral Objectives and Evaluation

Advocates of clearly stated objectives are not new to the educational narrative. The writings of Preston Search (15), Frederic Burk (16), Carleton Washburne (17), Helen Parkhurst (18), and E. L. Thorndike (19), all support this claim.

As early as 1915, Charters and Miller (20) used analysis of learner errors to identify and specify objectives for education. By focusing on what the learner was doing that could be observed, their work resulted in what may be the first collection of objectives which were restricted to describing learner performance.

Bobbitt (21), another early advocate of clearly stated performance objectives wrote in 1918:

> Human life, however varied, consists in its performance of specific activities. Education that prepares for life is one that prepares definitely and adequately for these specific activities. However numerous and diverse they may be for any social class, they can be discovered. This requires that one go out into the world of affairs and discover the particulars

> of which these affairs consist. These will show the abilities, habits, appreciations, and forms of knowledge that men need. These will be the objectives of the curriculum. They will be numerous, definite, and particularized.

Two other articles by Bobbitt (22, 23), propose this same view as do the writings of West (24), and Grimes and Bordin (25).

Among the most significant early contributions to the literature on behavioral objectives and their relationship to evaluation was Ralph W. Tyler. The concerns of Tyler focused upon questions of measurement. His argument was that clearly stated objectives were a necessary condition for the construction of appropriate measuring instruments. In 1934, Tyler suggested these characteristics for an objective:

> Each objective must be defined in terms which clarify the kind of behavior which the course should help to develop among the students: that is to say, a statement is needed which explains the meaning of the objective by describing the reactions we can expect of persons who have reached the objective. This helps to make clear how one can tell when the objective is being attained since those who are reaching the objective will be characterized by the behavior specified in this analysis. (26)

More recently Tyler (27) advocated a thorough examination of the needs of society as well as the needs of learners to develop statements of educational objectives.

Efforts have been made to describe educational priorities in terms of specific objectives. The Mid-Century Committee on Outcomes in Elementary Education attempted to identify and name desirable objectives of elementary education in terms of observable performances. (28) The Mid-Century Committee was sponsored by the Educational Testing Service, the Russel Sage Foundation, the United States Office of Education, and the Department of Elementary School Principals of the National Education Association. A similar effort was made by the Survey Study of Behavioral Outcomes of General Education which attempted to delimit the objectives of American secondary schools. (29) The Taxonomies of Educational Objectives offer classification systems for categorizing objectives into types of behavior, rather than the listing of individual objectives. (30,31,32) Gagne has proposed another classification system that organizes around conditions of learning. (33) The most recent fashion is to compile collections of behavioral objective statements. Notable among these efforts are PRIMES, The Westinghouse Learning Corporation, the UCLA Bank, NOBELS, Science-A Process Approach, and the Regional Education Laboratory of the Carolinas and Virginia. (34,35,36,37,38, and 39)

Behavioral objectives continue to be associated with evaluation efforts. John Flanagan expressed the contemporary concern for evaluation and the place of behavioral objectives when he wrote:

> However, large sums have already been spent on programs and innovations without adequate plans and procedures for evaluating their effectiveness. If these programs are to result in improvement and progress for American education -- rather than merely in changes that substitute partially effective procedures for the traditional ones -- educational outcomes must be systematically evaluated. (40)

Atkin has also endorsed the need for objective evidence from curriculum developers. Atkin wrote, "Those who suggest that curriculum be modified have the responsibility for demonstrating the desirability as well as the feasibility of the modification they suggest."(41)

Ebel lends additional substance to the objectives-evaluation association. He observed that "The first problem is to determine what the school's educational objectives ought to be. A second, closely related problem is to state these objectives clearly enough to provide unequivocal guides to test selection and use."(42) Mager has also reinforced the existence of this relationship when he wrote:

> Tests or examinations are the mileposts along the road of learning, and are supposed to tell the teacher and the student the degree to which both have been successful in their achievement of the course objectives. But unless goals are clearly and firmly fixed in the minds of both parties, tests are at best misleading, at worst, they are irrelevant, unfair or useless."(43)

Two excellent reviews of the literature on the current state of the relationship between evaluation and curriculum are presented by Thomas A. Romberg and Wayne Welch in the American Educational Research Association Review of Educational Research on Science and Mathematics Education.(44,45)

Summary: This part of the behavioral objectives literature is clearly exposition. No research was found. Gagne summarizes the problem when he observed "Bloom's techniques for defining objectives have been tried out on a number of universities with respect to achievement testing and evaluation programs. Perhaps it is unfortunate that the 'evaluation' carried out by means of these procedures has not itself been evaluated in some controlled fashion."(46)

Training Manuals on Behavioral Objectives

The interest in behavioral objectives has been accompanied by the development of training manuals on constructing behavioral objectives. Examples of available manuals are:

Duty Oriented Objectives U.S. Army
Army - Fort Lee, Virginia. 11984 - 66 - 1500.

The Development of Training Objectives. Robert G. Smith, Jr. Research Bulletin II. Human Resources Research Office, The George Washington University, Alexandria, Virginia. 1964.

Preparing Instructional Objectives. Robert F. Mager. Palo Alto: Fearon Publishers, 1962.

Behavioral Objectives in the Affective Domain. Albert F. Eiss and Mary Blatt Harbeck. Washington, D.C.: National Science Teachers Association, 1969.

Constructing Behavioral Objectives. Henry H. Walbesser. College Park: Maryland Book Exchange, 1970 (Second Edition).

Developing Attitude Toward Learning. Robert F. Mager. Palo Alto: Fearon Publishers, 1968.

Objectives for College Courses. A. M. Cohen. Beverly Hills, California: Glencoe Press, 1970.

Systematic Instruction. W. James Popham and E. L. Baker. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1970.

Writing Behavioral Objectives. H. H. McAshan. New York: Harper and Row, 1970.

Constructing Instruction Based on Behavioral Objectives, A Manual for College Teachers. Henry H. Walbesser, Edwin B. Kurtz, Larry D. Goss, and Richard M. Robl. Stillwater, Oklahoma: Department of Aerospace and Mechanical Engineering, Oklahoma State University, 1971

Behavioral Objectives as a Dimension of Communication

Perhaps the largest concentration of interest and research on behavioral objectives concerns the effects of providing the learner with various forms of information. The question central to the behavioral objective investigations in this area is this: Does the amount of information the learner possesses about the objectives of instruction affect his learning? Gagne argues that "Telling the learner what is to be his performance when learning is complete, functions as directions that seem to be of considerable importance to the learning process." (47) Behavioral objectives in this view are one category of information.

Gagne amplifies his view of the importance of instructions (as directions) by conjecturing that instructions in a learning situation fulfill four functions: (a) they inform the learner of the performance that is expected of him, (b) they bring about an identification of the elements involved in the task, (c) they help establish high recallability, and (d) they guide the learner's thinking.(48) He also suggests two potential explanations for the prediction that the probability of the learners attaining a solution will be reduced if instructions are not included. One explanation is that such instructions may provide continuing "direction" to learning, in the sense suggested by Maier.(49) This may mean that they establish a <u>set</u> which is "carried in his head" by the learner throughout the period of learning, and which makes it possible for him to reject extraneous and irrelevant stimuli. Another possible explanation is offered by Gagne is that directions telling the learner about his expected performance enables him to match his own responses with a response class he remembers, hence playing a reinforcement function. This might be called a "know when his is correct" explanation. Both explanations offer exciting possibilities for research. No test of these explanations was found in the literature searched.

Maltzman and Morriset reported an investigation on the effect of task instructions on the percentage of solutions for different classes of anagrams.(50) Instructions telling the subject that it would be helpful, during the experiment, to look for words referring to flowers, growing things, or their habitat were given to one of the groups. The subjects were told that they would be credited with a correct answer if they found some other solution. The effect of instructions on solving classes of anagrams was significant at the 0.05 level.

Maier's classical study on problem solving contributes to the knowledge about information effects on learning.(49) In this experiment, the learner was placed in a room which contained only a worktable. The subject was then given poles, wire, chalk, and several clamps. His task was to construct two pendulums such that each would make a chalk mark at a designated point on the floor when swung over it. Some of the subjects in the experiment were given additional instruction concerning previously learned principles such as how to make a long pole out of two short ones, using a clamp. Another experimental group was given an additional instruction which was referred to as "direction" by Maier. The results of Maier's study indicated that added instructions, as opposed to just stating the problem, increased the proportion of subjects who were able to solve the problem. The highest proportion of those who solved the problem was in the group which had added instructions and directions.

Smith pursued the investigation of the effects of instructions on learning by examining the effect of the learner being informed about the objectives of instruction.(51) The objectives and instructional activity in Smith's study dealt with mathematics. A sample of 162 eighth grade students was selected from ten classes labelled as slow learners. Each of the ten teachers was randomly assigned to one of two treatments and each student within the classes was randomly assigned to one of two treatments. The classes of one group of teachers received the unit in its entirety while the classes of the other group of teachers received the unit lesson by lesson. The students within the classes who were randomly assigned to two groups received different presentations of the instructional materials. One group of students received a printed instruction concerning the expected outcome of each lesson, while the other group was not given this instruction. The performance of the two groups of classes and the performance of the two groups of students were examined. The null hypothesis was retained for both performance comparisons. As one possible explanation for the null results, Smith raised a question about the information procedure he had employed. He wrote:

> Perhaps the reason for the lack of significant differences in this study was due to the manner in which the instruction was presented. Since the instruction was printed on the written materials, it was assumed that all students receiving the instruc-

tions would read them. However, this need not have been the case. The slow learning students might well have avoided these instructions and proceeded onto the materials themselves. There is no guarantee that the instructions had any impact at all on the experimental subjects.(51)

Engel continued this research direction by investigating an hypothesis similar to Smith's: namely, knowledge of the objectives in behavioral terms increases achievement.(52) Smith had offered as an explanation of the null results in his study that perhaps learners did not read the objectives. To overcome this difficulty Engel provided a mechanism for assessing whether the subjects actually read the behavioral objective statements. Early Childhood and Elementary Education majors were randomly assigned to two treatments: one with behavioral objectives and one without behavioral objectives. Both groups received the same instructional materials. The only difference was that a cover sheet stating the objectives of instruction in terms of learner behavior was attached to one-half of the instructional units. The findings supported the research hypothesis that information about the objectives of instruction increases the achievement of learners. Engel's data also provide support for the research hypothesis that subjects will achieve higher on a retention test if they are told in advance the objective of each instructional activity.

Research by Schuck(53) provided additional information about the effect of providing students with information about the intended learning outcomes of an instructional activity. The term "set induction" was used by Schuck. He defined set induction as follows:

> Inducing a learning set is the initial instructional act on the part of the teacher for the purpose of establishing a frame of reference deliberately designed to facilitate the creation of a communicative link between the experimental field of the pupils and the desired behavioral goals of the learning experience (the lesson).

Schuck found that pupils taught by teachers who had training in the use of set induction achieved better than pupils taught by teachers who did not have such training. Achievement in this case was measured by a multiple choice test of

240 items in biology. The study involved 108 pupils and 18 teachers both randomly assigned to the treatments. These findings seem to support those of Engel.

A study by McNeil (54) also contributes to the body of findings on the relationship of prior knowledge of behavioral objectives to acquisition. He reported on two groups of student teachers and their students. One group of student teachers were told that their grades would depend upon setting and achieving acceptable behavioral objectives with their students. This group achieved better than pupils taught by student teachers who were told that their grades would depend upon good lesson plans and the use of professional teaching methods. Both groups of student teachers were given the same description of the needs of the student. In connection with these findings McNeil also reported that the focus upon specific objectives did not appear to restrict the students to learning only the objectives stated to any greater degree than the students who were not given behavioral objectives, although no quantitative measure of this was made.

DeRose (55,56) reported two studies conducted at the Marple Newton High School in which students were supplied with behavioral objectives to help guide them in their independent study. The disciplines of biology, physics and chemistry were used and the results indicate that the pupils in the independent study program performed as well on the examinations as pupils in the conventional classrooms.

Doty (57) investigated the effectiveness of providing junior high industrial art students with objectives and practice on the acquisition of calculating the value and tolerance of axial resistors. His design called for four groups: (1) students receive specific objectives before instruction and practice on the actual task, (2) students receive specific objectives and practice on the task in a verbal symbolic format, (3) students received no objectives and practice on the task in a verbal symbolic format. His results indicated that students in the upper ability level did benefit in their immediate learning as a result of receiving prior knowledge of objectives and practice on the actual task. Average ability level students showed no significant difference in learning as a result of the treatments; however, low ability level students had equal or higher results than the average student when they received prior knowledge of objectives and practice on the verbal symbolic and actual task. It was also reported that students in all three ability groups who practiced but did not receive knowledge of the objectives had low immediate learning as compared to those receiving the specific objectives.

Conlon (58) compared the performance of seventh-grade students with and without prior knowledge of the objectives of an individualized science program. Her findings indicated that students with the prior knowledge of the objectives performed slightly higher than the students without the objectives; however, the difference was not statistically significant.

Dalis also investigated the effect of student knowledge of instructional objectives on achievement.(59) One hundred and forty-three tenth grade students in five health and safety classes constituted the sample. One third of each class was randomly assigned to one of three treatments: precisely stated instructional objectives, vaguely stated instruction objectives, and short paragraphs of health information. All subjects participated in the same instructional unit on growth and development. The data showed greater achievement for those students who received precisely stated objectives than for students in the other two groups. The treatment effect was significant at the 0.01 level.

Most investigators of the possible effect of telling learners the behavioral objectives have focused upon individuals as the experimental unit. Olsen(60) has made a significant departure from this tradition. He reports an investigation in which class effects rather than individual effects were measured. Eight classes received instruction in I.M.E. (Interaction of Matter and Energy) physical science with stated behavioral objectives and six classes received the same physical science instruction without knowledge of the objective. Olsen reports mean scores of classes with knowledge of behavioral objectives significantly higher than the no knowledge of behavioral objectives on an immediate posttest and on a retention test.

Summary: The literature offers cautious support for the hypothesis that providing the learner with information about expected learning outcomes affects his performance. The direction of the effect appears to be positive. It also seems necessary to control for "reading the information statements." If the subject does not read the information statements, the effect does not appear. The magnitude of the effect however, is not clear. How much of the variance in performance can be attributed to learner information about expected learner outcomes is not provided by the literature. These are worthy avenues for further investigation.

Behavioral Objectives, Efficiency of Acquisition and Retention

Rowan (61) observed that "most schools are organized so that a learner must complete a task within a given block of time. If he does not, his comparative evaluation reflects this, quite often just as though it were failure to acquire the learning goal rather than a slower learning pace. In a realistic sense, then, concern over learning rate [is] nearly as important as concern over learning itself."

The effectiveness of specifying objectives for training purposes is illustrated in a study report by Smith. (62) HumRRO Task Forecast developed a four hundred hour course based on a detailed study of the job of certain ordinance fire control technicians. The findings indicated that graduates of the course were as proficient in electronics troubleshooting as graduates of the regular thousand hour course. These findings suggest the research hypothesis that planning curriculum construction with objectives increases learner efficiency.

Mager and McCann report a study of the effects of specifying objectives. (63) In one group, the instructor controlled the sequence of content presented. In a second group, the subjects were permitted to select the content in accordance with a priority and a sequence they themselves assigned. The third group was given a detailed statement of the training objectives which included the kinds of questions they would be expected to answer. The subjects in the third group were allowed to instruct themselves in any order or by any means they chose. The subjects in the third group were told to report to the instructor when they believed they were ready to demonstrate attainment of any of the objectives. The time required for training was reduced by as much as 65 per cent for the third group without loss of proficiency.

Newman's research also supports the general finding that students informed of the behavioral objectives progress through an instructional unit in less time than students not informed of the objectives. (64)

Merrill reported a test of the hypothesis that subjects who receive specific review in learning a task will make fewer errors and take less time (1) on each successive lesson in the sequence, (2) on the criterion test, (3) on a three week retention test, and (4) on a three week transfer test than subjects who do not receive specific review. (65) His results showed no difference in number of errors per frame between the two groups and no difference in errors on the criterion, retention, or transfer measures. However, the no review group took significantly longer per frame and significantly longer per question on the three assessment measures. The review information might be thought of as identifying the important performances or objectives of each lesson. Information about the instructional objectives in this form also appears to have the effect of increasing the learner's efficiency. Schuck (53) in a studied cited earlier also reported significant (0.01 level) mean gains on a four week retention test for the set induced treatment group.

Rate of acquisition and resistance to forgetting may be altered by learner information about the instructional objectives.(66) The research hypotheses, telling the subject the behavioral objectives at the beginning of each instructional activity increases his rate of acquisition and resistance to forgetting, were tested. Thirty-six tenth grade students in geometry class were randomly assigned to one of two treatments: knowledge of objectives or no knowledge of objectives. The instructional materials, other than the objectives,(information) were the same for both groups. The learning hierarchy consisted of 17 behaviors on 9 levels dealing with methods of proof. A retention measure was administered eight weeks after the post measure was taken by each subject. The statistical hypotheses on rate of acquisition and resistance to forgetting were both rejected at the 0.01 level. Walbesser concludes--"The hypothesis that knowledge of instructional objectives increases the learner's rate of acquisition and provides a resistance to forgetting" are supported by the data.

Cook (67) conducted an investigation of the question raised by Engel. If some students are informed of the behavioral objectives and the learning hierarchy of a unit of instruction and another group of students receiving the same unit of instruction is not so informed, will there be differences in effect on retention. Eighty-eight elementary education majors in a four-year college were blocked on ability levels and randomly assigned to four treatments: one group received only the instructional material; a second group received the instructional material and behavioral objectives; a third group received the instructional material and the learning hierarchy; and a fourth group received the instructional material, behavioral objectives, and the learning hierarchy. The results of Cook's study support the hypothesis that providing students with statements and examples of behavioral objectives is an instructional method that will result in resistance to forgetting.

A study reported by John M. Smith (68) dealt with college students in a mathematics course. Smith studied the effect of providing the learners with behavioral objectives and a learning hierarchy prior to instruction upon rate of acquisition. His study involved 73 students in a study which included six weeks of independent study. Those students who finished the unit fastest also retained better what they had learned as measured by an unannounced post test given six weeks after the unit had been completed.

Behavioral objectives are descriptions of observable behavior. In the statement of a behavioral objective, the observable action is usually named by an active verb. A common practice among educators writing behavioral objectives is to identify classes of performance and name each performance class with one active verb. One widely used set of performance classes is the ten member collection employed by the American Association for the Advancement of Science, Commission on Science Education in the elementary science curriculum Science - A Process Approach. Walbesser (69) has provided a definition of each of the ten action verbs in this particular collection. Each of the ten action verbs name a unique performance class. Rosen (70) investigated the question of whether there are differences in rate of acquisition or rate of forgetting for behaviors from these various performance classes. Three behavioral objectives from each of four performance classes -- identify, construct, describe, and demonstrate -- were randomly sampled from the behavioral objectives of Science - A Process Approach, Part D.

A self-instructional program was created for each behavioral objective sampled. Reading level and number of pages per program were controlled for the twelve instructional programs. No differences were found in rate of acquisition or in rate of forgetting. Rosen concludes there appears to be no need for allocating "different amounts of instructional time" for behaviors selected from these four performance classes. In light of Rosen's findings, the conjecture that the ten Science - A Process Approach performance classes are a means of ordering the complexity of behavioral objectives finds little support.

Summary: The findings offer cautious support for the hypothesis that knowledge of the objectives of instruction in behavioral terms increases the rate of acquisition and slows down forgetting. The magnitude of these effects is not clear. However, the resistance to forgetting results do appear to be stronger than the rate of acquisition findings when intact classes are involved. These do appear to be variables worthy of further investigation.

Behavioral Objectives and the Teacher

Given information in the form of statements of behavioral or nonbehavioral objectives, can teachers distinguish between them and demonstrate this knowledge by their instructional choices? What do teachers do when they are given behavioral objectives to use? The research on these questions has, for the most part, focused upon one investigative theme -- Do teachers act differently upon being given statements of objectives which are more specific? An ERIC report by Cook and Neville (71) examines the literature on evaluation of teachers and its relationship to behavioral objectives.

Ammons investigated the question of whether teachers could distinguish between statements of behavioral and nonbehavioral objectives. (72) A list of thirty statements of instructional objectives were presented, some of which were nonbehavioral. The teachers were to select those statements for which they could describe an objective criterion for evaluation. The findings suggest that although changes in student behavior were not mentioned in the nonbehavioral objectives, the teachers made judgements that required behavioral performances on the part of the learner. The general character of his finding is suggested by Ammons' observation that "- - - almost any kind of statement was considered as a statement of an objective."

Baker's research supports the finding of Ammons. (73) Three lists of objectives were constructed by Baker and then the lists were randomly assigned to high school social science teachers. One list consisted of statements of nonbehavioral objectives, the other two lists consisted of statements of behavioral objectives. The teachers instructed the students in their classes employing the objectives on their assigned list as the instructional guide. Baker reports these findings: (1) teachers were unable to match the behavioral objectives with activities required in the objective, and (2) no significant difference in achievement was found among the three groups. Baker offers the explanation that the lack of differences may be attributed to the teacher's inability to provide classroom activities in agreement with a given behavioral objective or their inability to identify test items which assess a particular behavioral objectives.

McNeil's (54) research reported earlier also contributed to the study of the relationship of prior knowledge of behavioral objectives to acquisition. McNeil used student teachers randomly assigned to treatment groups in his investigation. In one experiment he found that student teachers who negotiated an agreement with their supervising teachers as to the behavioral objectives of the course were perceived as being superior to the control group student teachers who did not negotiate such agreements. A second study found that student teachers preferred having their grades depend upon pupil progress as determined through the use of behavioral objectives.

Summary: More research needs to be conducted on the potential relationships between behavioral objectives and the teacher before any clear direction is apparent. One hunch that emerges from the reported investigations is that teachers must be taught how to use behavioral objectives in planning instruction and evaluation, if they are to be used at all.

Behavioral Objectives and Affective Variables

Two studies on the relationship of behavioral objectives to affective variables were uncovered in the literature search.

Tiemann (74) investigated student preferences toward the specificity of statements of objectives. Eight videotaped lectures were presented to two groups of college students. One group was also provided with a set of general objectives for the lectures and a second group was given a set of behavioral objectives for the same lectures. Tiemann's findings show the students with a greater preference for more objectives; greater use of more specific objectives, and a more favorable attitude toward the presentation of lessons with specific objectives.

Rowan (61) investigated the effect of giving pupils prior access to behavioral objectives on attitudes toward behavioral objectives. Three fifth grade classes with a total of 92 pupils from three separate county public school systems of Maryland participated in the investigation.

Each pupil studied two programmed instructional units in two formats. Under one format the pupil was informed of the behavioral objectives of each subsection before he studied that subsection. Under the second format the pupil was not informed of the behavioral objectives. Instead, he was given an equivalent amount of non-directive but related reading prior to studying each subsection. These two versions of the programmed materials were color coded. The program with behavioral objectives always had a blue cover sheet on each subsection. The program with non-directive discussion, but no objectives, always had a pink cover sheet on each subsection. The pupils were informed only that they were involved in a contest to determine if they would do better studying with the blue program or the pink program.

After each pupil had studied a program in both the blue version (with behavioral objectives) and the pink version (without behavioral objectives), he was given a choice as to the version which he would use on the third program. This choice was offered by saying:

> Now that you have had a chance to study in both the blue and the pink programs, there is no real need to have you study the third program in a particular version. I have enough of both colors so that you may choose the one which you would rather study, perhaps the one you felt helped you more. If you don't really care, then just pick whichever one comes to your mind first. Write your choice at the top of your paper and as I come by I will give you the one you chose.

The procedure was also followed to provide an additional support for the affective findings. An assessment was made to determine whether the students could distinguish between the behavioral objective and no behavioral objective treatments. A "dummy" program was prepared with cover sheets designed similarly to those used in the actual program. The cover sheets contained behavioral objectives or non-directive comments written in the style which had been used. The difference was that these cover pages were not color coded. They were all prepared in white. The subjects were asked to decide whether they should be pink or blue. It was assumed that correct identification would be evidence of having read and interpreted the sheets used on the programs of the experiment.

The findings reported were the following:

1. The treatment, instruction preceded by behavioral objectives, was chosen significantly more often than the no behavioral objective treatment.
2. Students were able to distinquish between programs with and without behavioral objectives.

<u>Summary</u>: It is not sensible to suggest anything but the most tentative conclusions in this area. One hunch that these findings suggest is that students can distinguish between the presence and absence of specific objectives. Another is that students prefer self-instructional activities with statements of behavioral objectives.

Behavioral Objectives and Psychomotor Variables

No investigations dealing with the effect of behavioral objectives on psychomotor variables were found. Some work is needed in this area.

Other Variables of Some Interest

Since behavioral objectives name behaviors to be acquired by individuals, direct measurement of the acquisition of each behavior requires individually administered tests. Walbesser (75) among others has made the argument for individual assessment whenever the acquisition of human behavior is being measured. Group assessment is often used because of economic reasons -- it is less expensive to administer tests to a group than it is to administer tests separately to one individual at a time. The convenience of forced (multiple) choice tests also aids the popularity of group assessment.

Walbesser and Carter hypothesized that changing the assessment task from individual to group format decreased the number of subjects able to complete the task. Their study indicated that with the performance classes of <u>construct</u>, <u>demonstrate</u>, <u>describe orally</u>, a significant difference occurred in the number of subjects that could reach behavioral criterion when the individual assessment tasks were changed to group assessment tasks. With the performance classes of <u>naming</u>, <u>using writing</u>, <u>identifying</u>, and <u>stating a rule in writing</u>, no significant differences between individually administered tasks and group assessment tasks were found. (76)

Neither stimulus nor response generalization has received very much attention in the research literature. Implicit in the theory of behavioral objectives is the assumption of substantial generalized ability once an individual has been judged to reach criterion. One stimulus generalization study was found. Carter (77) reports data in support of the research hypothesis that behavior acquired in one content setting generalizes to other content settings. She also offers the conjecture, based upon these same data, that learner cognitive style may be a variable that affects both behavioral acquisition and the magnitude of stimulus generalization. Clearly, much additional work is needed before any conclusions can be drawn about the relationships of behavioral objectives to cognitive style, magnitude of stimulus generalization, and conditions influencing generalization.

Summary for Section One

Writing, discussing, and applying behavioral objectives have become popular causes in school curriculum during the decade of the 60's. Discussions, both pro and con, have been the principal products of the decade's activity with behavioral objectives.

Data gathering with behavioral objectives as a manipulated or responding variable has received only modest attention. One possible explanation for this state of affairs is that it is simply easier to talk about something than it is to collect data to resolve a question.

Effects of behavioral objectives on learning or instruction are as yet unclear. The grand promises of behavioral objectives as a remedy for major educational ills as well as the forecasts of lockstep, dehumanized curricula predicted by the opponents of behavioral objectives have each been found wanting. "Telling the learner the behavioral objective" has been the most popular manipulated variable; with acquisition, rate of acquisition, forgetting, and rate of forgetting the four responding variables. Telling the learner the behavioral objective does not appear to have consistent effects upon acquisition. This same manipulated variable showed significant effects upon increasing rate of acquisition in military training studies. Strength of the relationship in pre-college and college curricula has not been clearcut. The direction of the effect is the same as in military studies, but the magnitude is smaller. Similar comments can be made for the reported findings on forgetting and rate of forgetting.

Research on behavioral objectives may also be summarized in terms of hypotheses supported. Such a summary follows.

I. Research Hypothesis: Telling the learner the behavioral objectives increases achievement.

Research Supporting the Hypothesis	Research Not Supporting the Hypothesis
Norman F. F. Maier 49	Stanley A. Smith 51
Maltzman and Morriset 50	James DeRose 55, 56
Roberta A. Engel 52	C. R. Doty 57 (Average Ability Students)
Robert F. Schuck 53	Betsy Conlon 58
John D. McNeil 54	J. Marvin Cook 67
C. R. Doty 57 (High and Low-Ability Students)	Thomas E. Rowan 70
Gus Dalis 59	Jenkins and Deno 152
Robert Olsen 60	

II. Research Hypothesis: Telling the learner the behavioral objective increases rate of acquisition.

Research Supporting the Hypothesis	Research Not Supporting the Hypothesis
Robert G. Smith 62	John M. Smith 68
Mager and McCann 63	
Slater E. Newman 64	
M. Daniel Merrill 65	
Henry H. Walbesser 66	

III. Research Hypothesis: Telling the learner the objective increases resistance to forgetting.

Research Supporting the Hypothesis	Research Not Supporting the Hypothesis
Robert F. Schuck 53	
Henry H. Walbesser 66	
J. Marvin Cook 67	
John M. Smith 68	

IV. Research Statement: Teachers can distinguish between statements of behavioral objectives and statements of nonbehavioral objectives.

Research Supporting the Statement	Research Not Supporting the Statement
	Margaret Ammons 72
	Eva L. Baker 73

V. Research Statement: Students show a more positive attitude toward instructional objectives stated as behavioral objectives.

Research Supporting the Statement	Research Not Supporting the Statement
Philip W. Tiemann 74	
Thomas E. Rowan 61	

VI. Research Statement: Group performance measures underestimate the acquisitions of the learner.

Research Supporting the Statement	Research Not Supporting the Statement
Walbesser and Carter 76	

VII. Research Statement: There exist differences in rate of acquisition for different performance classes.

Research Supporting the Statement	Research Not Supporting the Statement
	Richard F. Rosen 70

Section Two

Learning Hierarchies

The learning hierarchy section is organized into three parts. The first part explores the definitions of "learning hierarchy" and procedures for constructing learning hierarchies. The second part describes research concerned with variables that affect learning hierarchies and that are affected by learning hierarchies. The third part of the review concerns psychometrics of learning hierarchies.

Part One, Defining and Constructing Learning Hierarchies

In a report of a study of mathematics learning in 1962 Gagne (78) applied the term, "learning hierarchy" to refer to an ordered collection of specified intellectual capabilities. Gagne hypothesized that any intellectual skill can be analyzed into a hierarchy of subordinate intellectual skills. These subordinate intellectual skills (behaviors) are arranged in a sequence such that all the necessary prerequisite behaviors are listed below a terminal behavior. Prerequisite behaviors are also called enabling behaviors by some researchers. The acquisition of all subordinate behaviors listed in the learning hierarchy is hypothesized to be required for the acquisition of the terminal behavior of the learning hierarchy.

Sequencing by Task Analysis: Mechner (79) provided a general discussion of sequencing and its relationship to behavioral technology. He suggested these steps in the development of an instructional program:

(a) specification of behavioral objectives
(b) analysis of the subject matter in terms of component discriminations, generalizations, and chains
(c) sequencing of these components for "effective" learning.

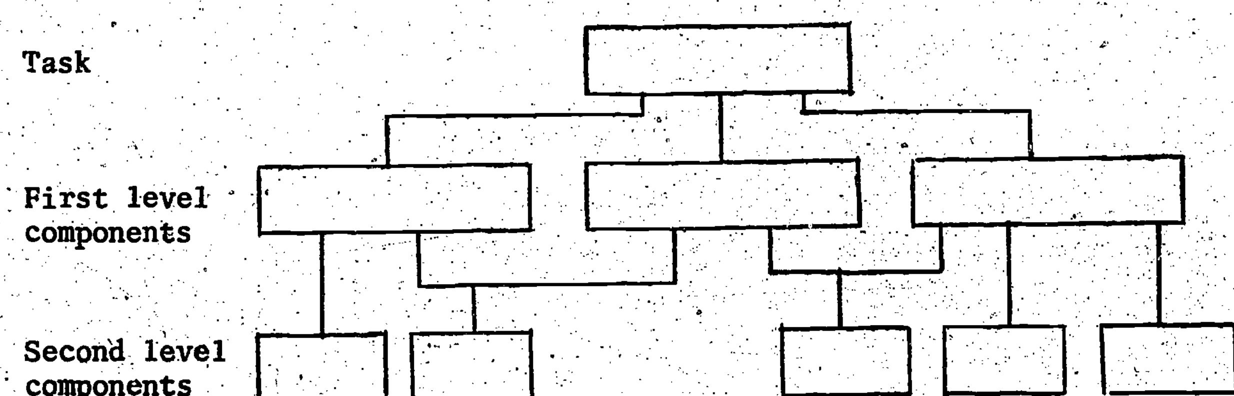
The second and third steps identified by Mechner combine into a procedure more commonly known as task analysis.

The analysis of a task into instructional components has been widely used in the design of training materials for industry and the armed services. Miller's work (80,81,82, and 83) in military training applications of task analysis border on being classics. Recently, a few examples of this technique applied to the pre-college school curriculum have also been reported in the literature. Examples of such products are the basic and integrated process hierarchies of the Science - A Process Approach curriculum (84), the inservice elementary mathematics hierarchy on algorithms in Games and Algorithms (85), the Geometry hierarchy produced by the Montgomery Public School System for its secondary school geometry course (86), Maryland (87) and Delaware (88) State Departments projects on behavioral objectives and learning hierarchy construction.

A non-experimental research report by Petro (89) involved both sequencing and hierarchies. Petro derived a set of hierarchies and behavioral objectives for technical accounting. The model used for the derivation of instructional objectives consisted of ten operational steps and combined features of different approaches to deriving objectives including the Mager model, the Bloom and Krathwohl taxonomies and the Gagne learning system.

There exist numerous variations on the task analysis theme. For example, McKnight reports on a procedure for creating a "Task Identification Matrix." (90) Each cell of the matrix is the intersection of one supply operation and one commodity. Here the content of each cell lists the tasks required to carry out an operation. Such a detailing description is often done so as not to overlook any necessary steps.

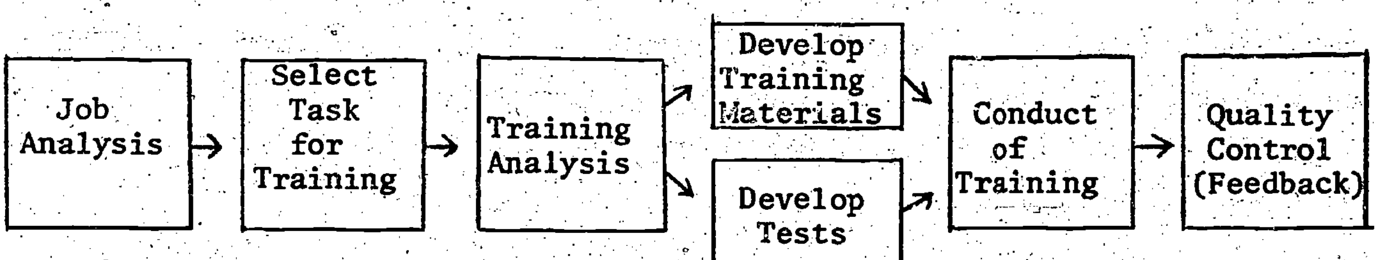
Perhaps the best known form of the task analysis procedure is the one described by Smith. (91) The designer begins by asking the question, "What must the learner be able to do if he has been told to perform a task, but has been given no specific training in that task?" The result of responding to such a question organizes the given task into components that often assumes a pyramidal appearance. The following is an illustration of such a hierarchy:



Observe that the application of a task analysis procedure does not guarantee an "effective" sequence, it merely produces an hypothesized sequence that may succeed. Each task analysis generates a "best guess" sequence with respect to the author's experiences. How well the sequence succeeds (that is, how many learners are able to perform the final task after following the sequence) is one measure of validity for the sequence. Various validity levels are sought by curriculum developers. In Smith's manual, an 85 percent acquisition level for the final task is considered desirable. In the work of Gagne and his associates a 90 percent acquisition level is usually sought.

Instructional materials designed by task analysis procedures usually employ sequencing rules. In the Continental Army Command manual on course design the rule is "given an objective , ask yourself whether this objective should be reached before or after the last one selected."(92) This procedure, called "consensus sequencing", results in the identification of a dependency ordering for the objectives. Another variation of a content-objective matrix is also offered by this manual as a means of compiling an inventory of the task.

In the literature, task analysis is often one component of a management sequence. Typical of such management-development relationships is the following one described by Crawford (93):



Observe that task analysis is the second step in this chain of events. Training analysis follows the identification of the training task. Although individual modifications are made by almost everyone who engages in such management task analysis, the sequence followed is isomorphic to the one just outlined.

Construction of a Learning Hierarchy By Task Analysis: An extensive analysis of the research and expository literature on task analysis and learning hierarchies was published by Leslie Briggs in 1967. (94) Since this review is available through the ERIC system of documents, the current review does not attempt to retrace this same material. Rather, this review focuses upon research subsequent to the Briggs review.

The construction of the first edition of a learning hierarchy of supporting behaviors upon which the final behavior depends is accomplished by task analysis. A final behavior is specified and described as a set of reliably observable performances that a learner can exhibit to signify his acquisition of the behavior. Analysis of the behavior is begun by formulating an answer to the question, "What should an individual need to be able to do in order to exhibit this behavior, after being given instructions?" The result of the application of this question to the final behavior yields one or more subordinate behaviors. The question is then applied to each of the subordinate behaviors in order to identify behaviors subordinate to each of these behaviors. The iterative application of this method results in several layers (or levels) of supporting behaviors that constitute a hierarchy of behaviors hypothesized to be necessary and sufficient for the acquisition of the final behavior. The analysis (iteration procedure) terminates at a level which describes behaviors that the learner can be assumed to have available to him when he begins instruction. In summary, the specification of a learning hierarchy provides a behavioral description of the component behaviors that are hypothesized to be necessary and sufficient to acquire the final behavior and assigns them an order. An excellent description of this procedure was provided by Gagne (95) in a discussion of his research with Brown (96). After the terminal behavior has been identified

> "the next step was to figure out what these 'subordinate skills' might be. Beginning with the final task, I found it was possible to identify nine subordinate capabilities, related to each other in an ordered way, by successively asking the question concerning each task, "What would the individual already have to know how to do in order to learn this new capability simply by being given verbal instructions?" It is probably of some importance to note that the kinds of capabilities identified in this manner did not directly pertain to number series, but rather included such skills as the following:

(a) identifying the location of numerals in a tabular array by means of letters giving their row and column location;

(b) completing statements of equality by supplying missing numbers in equations containing mixed arithmetic operations;

(c) identifying the numbers or letters in a tabular array which formed certain spatial patterns represented by lines connecting at 90° and 45°.

I emphasize that the subordinate skills so identified are not related to number series in a logical sense; what they are related to, psychologically, is the kind of behavior the learner has to engage in if he is going to be successful at figuring out from a tabular array of number series properties, how to formulate an equation for their sum."

It is important to note that a learning hierarchy constructed in this manner (task analysis) is an hypothesis or, more properly, a sequence of hypotheses of learning dependency. The hypothesized learning hierarchy is not a description of truth. A learning hierarchy for a given behavior does not represent a unique or most efficient route for any given learner. What they do represent, without validity estimates, are plausible learning sequences; and with validity estimates, they become probable expectations of greatest positive transfer for a learner population defined in terms of their entry behaviors.

Learning hierarchies concern acquisition relationships of positive transfer among behaviors (intellectual skills) and not descriptions of how one acquires the knowledge described by these behaviors. Gagne made this point in his 1968 address to the American Psychological Association. (95) He observed:

> The question is, what exactly are these entities, sometimes called capabilities, that make up a learning hierarchy? The answer I would now give is the following. They are intellectual skills, which some writers would perhaps call cognitive strategies. What they are not is just as important. They are not entities of verbalizable knowledge. I have found that when deriving them one must carefully record statements of "what the individual can do,"

and just as carefully avoid statements about "what the individual knows."

Summary: Task analyses by one or more "experts" is one method of constructing a learning hierarchy. This often called an "arm-chairing" procedure, since no learner input is obtained in the initial construction of the hierarchy. Expert judgement is used to guide the construction of the sequence. The next two sections consider alternative methods for constructing a learning hierarchy.

Student Generated Learning Hierarchies: One important class of alternatives to the "arm-chairing" procedure for constructing a learning hierarchy is to be guided solely by learner input. It is implied in the literature for student-generated learning sequence that when students are given an opportunity to select and sequence instructional material to reach a terminal behavior, their choice and organization of material is not necessarily the same as that of a curriculum developer's.

An investigation by Mager (43) was conducted to ascertain (a) whether learner-generated sequences would be similar to instructor-generated sequences, and (b) whether or not there was any commonality in sequences generated by students. A single learner, who had expressed a desire to learn something about the subject of electronics, was taken to a seminar-sized classroom equipped with working tables and chalkboard. The subject was informed that he would try to behave only as a responsive mechanism. That is, the instructor would offer information only in response to questions from the subject, and would continue to offer information in any area of electronics. This procedure was adopted to determine whether or not there was commonality of student-generated sequences, even though no direction or specific objectives were offered by the instructor.

A total of six adults (three male and three female) participated in the experiment. There are four principal findings of the experiment: (a) the learner begins his course in electronics with an entirely different sets of topics than does the instructor.

When the outlines of eight different basic electronics courses taught by industry or by the military were examined, it was found that all of them began with the subject of magnetism or with

> electron theory...If, on the other hand, an electronics course was sequenced by the learners, it would begin with the subject of the vacuum tube. All of the learners, used in this preliminary investigation asked for information about the vacuum tube during the first 40 minutes of instruction. (43)

(b) Even though no specific objectives were provided with respect to learning outcomes, and the subjects were not restrained to any particular area of electronics, there was commonality between the independent content sequences generated by learners. The commonality of subject matter was greatest at the outset of instruction. (c) Initial interest was centered around the concrete, rather than the theoretical, in the "how" rather than the "why." (d) The learners were interested in the functional rather than the structural, and, consequently, the sequences they constructed progressed from simple to complex tasks. Mager interpreted the implications of the study in the following way:

> The results clearly suggest that the content sequence most meaningful to the learner is different from the sequence guessed by the instructor to be the most meaningful to the learner. (43)

This conclusion goes well beyond the data and, as such, suffers from being an overgeneralization. To be sure, these findings suggest some support for the hunch that learners' sequencing may not always be congruent with instructor sequencing. Further, Mager suggested that if an adult learner was provided with behaviorally state objectives and control over his learning, he would reach the objectives by dovetailing what he needed to know with what he already knew. This inference was tested in a later study by Mager and McCann.

The purpose of the experiment by Mager and McCann (63) was to "obtain data pertinent to the instructional effectiveness of two variables: (1) learner control of curriculum and (2) instructional objectives." Before permanent assignment to a position in an electronics corporation, newly graduated engineers participated in a training course six months in length. Training included theory, machine and instrument operation, manufacturing processes, and company procedures. The first six weeks of the course were devoted to formal lecture, the second six weeks were such that each trainee rotated through various departments via temporary assignments to the manager or expert in the department. During the last three months of the course, each individual was assigned as an assistant to an engineer. Because of the observed ineffectiveness of this approach, Mager and McCann decided to investigate the feasibility of instruction via student-generated learning sequences.

In an experimental group, students had complete control over what they learned, when they learned it, and how they learned it. They could ask for instruction from anyone in the division, and need not accept the information if they so desired.

One important difference between this study and the previous one was that in this study, the students were given twenty-four pages of detailed course objectives which specified the desired terminal behaviors. The total effect was that in order to reach the objectives the students had to decide what they needed to learn in addition to what they already knew. Some findings of the study were:

1. Training time was reduced 65%. Within six to eight weeks after training commenced, all students were permanently assigned.
2. The graduates of the program appeared better equipped than their colleagues who were graduated of previous cycles. Specifically, their division managers considered these engineers better trained, more knowledgeable, and more confident.
3. Although the sequence of organization varied from student to student, in no case was it identical with the sequences used previously.

Mager (97) conducted still another study that investigated content sequencing through student input. In this study, there was interest in determining the meter reading skill of several kinds of experts. An automated meter reading examination was administered to a group of physicists, engineers, and technicians. The final score for each of these groups was approximately 80 percent. When housewives were given the same examination, without any previous training, they averaged 40 percent. Although all the housewives claimed ignorance in the areas of electronics and reading, and although they had no formal training in this or related areas, their performance when compared to the "experts" was surprisingly high. According to Mager, this study implied that no matter how naive a subject claims to be, he generally possesses a considerable amount of relevant knowledge.

With a similar research stratagem, Mager and Clark (98) conducted an experiment to determine whether qualitative knowledge of result could be used to teach a subject information for which there was no right or wrong answer. "The object was to determine whether subjects could learn to discriminate different smoothnesses of metal surfaces when their responses were confirmed by the percentage of expert agreement with the response rather than by an indication of correctness or incorectness."

An "expert" was defined as an individual who had final authority over the disposition of the metal material in question, rather than in terms of a specified collection of skills. The stimulus items were judged by thirty-six experts and their averaged judgement used as the standard criteria.

The findings of the experiment revealed that the performance of the experts turned out to be identical in every respect to that of the control group receiving no training whatsoever. Mager and Clark observed "...some experts know a good deal less than we give them credit for." They continued in the following way:

> There have been countless studies, for example, in which the ability to predict human behavior was studied as a function of training and experience level. The ego-deflating results have uniformly demonstrated that the predictions of those naive organisms commonly referred to as "college sophomores" and "underpaid secretaries" were essentially as accurate as judgments made by highly trained and experienced clinical psychologists. The expert, in other words, didn't made judgments any better than the novice.

The findings of this study concur with those of Newman (64) and Hatch (99).

Allen and MacDonald (100) conducted an experiment in which one group learned from a linear program, while each member of a second group was provided with objectives and an instructor that could be questioned at will. The members of the group which had control over the curriculum performed almost as well as those learning from the linear program and required only half the instruction time needed by those using the program. An observation made by Allen and MacDonald was that if one had watched the subjects, he would probably have predicted poor acquisition of the terminal behavior because of the chaotic method in which they asked questions of their informed source. Nonetheless, they performed almost as well as the program group and in nearly half the time. The findings of this study were in agreement with those of Campbell and Chapman. (101)

In a similar study, Kaplan (102) designed an experiment to determine into what sequence students order information. The tactic of having the instructor act as a responsive mechanism was employed. The subject matter was that of "vectors" and the findings of the study substantiate those of Mager. Specifically, the students moved from concrete to abstract, there was greater commanality of questions at the outset of instruction, and all students, no matter how naive they claimed to be, possessed some knowledge of vectors. Kaplan compared the sequencing of the topics by the students to three standard textbooks and noted: "The assumption that the 'best' sequence for the student is the instructor-generated sequence should be modified."

Shannon investigated (103) the question of whether achievement would be affected differently if two groups of students were taught identical content, one by a teacher-determined sequence and the other by a student-determined sequence.

Data was gathered on fifty-five students taught a series of 25-minute lessons on the topic "analysis of basic bookkeeping transactions" in one of two treatments. The first group was taught by a teacher-determined sequence of instruction. This sequence was based upon a behavioral learning hierarchy. The second group was taught by a student-determined sequence of instruction. The terminal behaviors of the learning hierarchy were given to the students in the second treatment. Statement of the terminal objectives were provided in written form. Students worked in groups of three-to-five, using the teacher as a response mechanism. The same teacher taught both treatment groups. No texts or outside sources were provided during the eight days of instruction.

No statistically significant difference was found between the mean scores of treatment groups on either an achievement teat or a transfer test. Shannon concludes that learners are as effective in sequencing instruction for themselves as instructors hypothesizing an effective common sequence for all learners.

<u>Summary</u>: There appears to be support, in the research literature, for the findings that "expert" generated learning hierarchies and student generated learning hierarchies with the same terminal behavior are not equivalent. Whether these differences affect acquisition, rate of acquisition, or retention is unclear at this

point and needs systematic investigation.

Student - Instructor Generated Learning Hierarchies: Another significant collection of alternatives to the "arm-chairing" procedure or the student procedure for constructing a learning hierarchy is to combine student input with the "experienced based" input of the professional instructor.

The first approximation of a learning hierarchy is often constructed by two or more content experts drawing upon their experience with a particular content field. Usually by exchanges of information, the discussants will "arm-chair" a learning hierarchy. Validity data are then gathered and revisions made. Clearly such a procedure is highly vulnerable to personal bias and may produce a poor first approximation in need of extensive revision. Indeed, it is the experience of many who construct and validate learning hierarchies that three or more revisions are ordinarily necessary to achieve an 80 percent level of acquisition and some never achieve this level. (104) One alternative to the "arm-chairing" procedure is the learner generated tactic discussed in the previous section.

Another alternative combines both expert input and student input. This second alternative strategy for learning hierarchy development is suggested by the work of Davidson (105), Eisenberg (106), and McKeen (107).

The procedures utilized in the construction of the initial hierarchy were essentially those described in "Selecting Tasks for Training," developed by the United States Continental Army Command. (92) The actual contruction procedure begins with the identification of a terminal behavior for the learning hierarchy about to be created.

The selection of the terminal behavior for a learning hierarchy in this construction procedure begins with the assumption that each discipline can be considered as being the union of certain sets of subareas. For example, several subareas of elementary high school algebra are linear equations, quadratic equations, inequalities, and graphing. A subarea must be instructive in its own right. For example, with reference to elementary high school algebra, a subarea would be the solution of linear equations of the form $ax + by = c$, where a, b, and c are rational numbers. However, the process of finding the integral solution set to the equation $3x + 2y = 4$ would not be considered a subarea because of its lack of generality. Once the curriculum designer had identified a subarea, it is then transcribed into a set of behaviors that are necessary for successful mastery of the subarea.

Transcribing a subarea into representative questions or problems is the next task undertaken in the Davidson-Eisenberg-McKeen procedure. However, problem definition is not simple. As David Hilbert (154) stated:

> A mathematical problem should be difficult in order to entice us, yet not completely inaccessible, lest it mock at our efforts. It should be to us a guide post on the mazy paths to hidden truths, and ultimately a reminder of our pleasure in the successful solution.

The following are necessary characteristics of a subarea:

1. Is the scope of the subarea general enough so that it may be considered a major facet of the discipline?
2. Are the questions and problems representative of skills required in the subarea?
3. Are the questions and problems representing the subarea non-trivial to the students for whom the curriculum is being developed?

They counsel that if each of the above questions can be answered in the affirmative, then the designers are ready to begin the construction of a learning hierarchy.

For each subarea of a given course of study, the designer identifies approximately six prerequisite topics necessary for a successful realization of the subarea. Using the relation "is a prerequisite to", these topics are arranged into the hierarchial form. For example, consider elementary mathematical analysis as the focus of concern and constructing proofs concerning the existence of limits of real-valued sequences as the subarea. Several prerequisite topics necessary for a successful realization of this subarea might be: applying the basic limit theorems of real-valued sequences, applying the definition of a limit of a sequence, classifying real-valued sequences, and determining a general term in a real-valued sequence.

The choice of identifying "six" topic cells is an arbitrary one. However, it should be noted that this development differs from the "arm-chair" approach in the sense that the designer globally analyzes the subarea, and chooses approximately six prerequisite topics needed for a successful realization of it. In choosing prerequisite topics for a given subarea, the designer asks himself the following question: "If I had to select six topics one would need to know in order to demonstrate competence in this subarea, I would choose ..."

Once the skeletal topic hierarchy has been constructed, each of it lls is translated into a set of performances which are indicative of compet in the topic. Hence, a second skeletal hierarchy consisting of performance tasks is constructed. At this stage of the procedure two skeletal hierarchies have been constructed. Both hierarchies are skeletal in the sense that they do not contain all of the prerequisite behaviors necessary for the acquisition of the terminal behavior.

A problem representative of the lowest cell in the topic hierarchy is selected. This problem is presented to a group of four students; the other groups are dismissed for the present time. The pedagogic style is that of Shulman's interpretation of employing a behavioral hierarchy in a discovery instructional setting. That is, the instructor presents the problem to the students of the group and then, with the recorder, observes the relevant behavior exhibited, including the questions raised pursuant to a solution.

The students are not permitted to work independently of "their" solution to the problem, but are encouraged to share their ideas and suggestions for a solution with all members of the group. It is assumed in the model that the solution to the problem be a group solution, not an individual one. To help accomplish this, the students are requested not to take notes until the last ten minutes of the class period. At that time, they outline the activities and problems under discussion for their own record. This restriction is intended to encourage the students to function as a group.

The student input is recorded through the use of an instructor serving as a recorder. Since there is also a need for a classroom instructor, at least two professionals are required in this model during the hierarchy construction. How many recorders should be employed for maximum effectiveness? Clearly one recorder is not as efficient with respect to information gathering as more than one. However, Haiman's text (108) on group leadership and democratic action offers findings to support the hypothesis that group activity is inversely proportional to the number of authority figures present. Because of the desire for maximum student activity the model calls for one, and only one recorder.

As a solution to the problem evolves, it is the responsibility of the recorder and instructor to identify topics discussed and questions asked during the session.

The instructor plays the role of a resource individual; a person to whom the members of the class can approach for guidance in their work, but one who will not do their work for them. The students may make many false starts before they identify a plausible approach. At times, the students will not have the slightest notion as to how they can attempt a solution. At this point, the instructor gives the students an "initiator activity." An initiator activity is defined as a hint. It is an activity that will help the students construct a solution to the problem. For example, the instructor might state: "What would happen if you consider...," or "Why did you disregard your previous idea of...," or "Did you do anything yesterday that might help you with...?" The initiator activity might also take the form of the instructor drawing a diagram upon the chalkboard. An initiator activity is a hint, not an explicit set of instructions to guide the students to a solution to the problem. Regardless of the type of initiator activity, two conditions must exist before an initiator activity can be used:

1. The instructor judges that group progress with respect to a given problem is unlikely without an initiator activity.
2. Group activity has come to a standstill for a period of at least three minutes. (106)

By identifying the behaviors and topics for which the students collectively exhibit a need as they attempt to construct a solution to a given problem, the designers are able to expand upon the skeletal hierarchy. Behaviors identified by the students as prerequisite to a given cell are inserted into the skeletal hierarchy.

<u>Summary</u>: The student-instructor procedure for constructing learning hierarchies provides for a much broader base of input information during the assembly of the initial approximation. One research hypothesis suggested by this procedure is that the broadened input reduces the magnitude of each hierarchy revision. Another hypothesis related to this procedure is that the total number of revisions

needed to achieve a given validity level is reduced.

Research Foundations of the Davidson - Eisenberg - McKeen Model: The basis of the Davidson-Eisenberg-McKeen procedure for generating learning hierarchies is an outgrowth of Davidson's work with small groups at the Universities of Wisconsin and Maryland. (109) The procedure also encompasses the theoretical implications of Bruner's Toward a Theory of Instruction (110) and Gagné's task analysis procedures. (111)

The entire developmental procedure is embedded in a "democratic environment model" based upon White and Lippitt's findings on autocracy and democracy. (112) These studies have shown that the giving of information, stimulation of self-direction, group openmindedness, and work efficiency without supervision were greatly enhanced in a democratic as opposed to an autocratic or laissez-faire atmosphere. The democratic atmosphere is achieved by the students and experimenters being on a first-name basis, joint student-experimenters' decisions on grading, and group solutions to problems. The results of the studies of White and Lippitt have been confirmed by the research of Faw (113) and Smith and Johnson. (114)

Concerning anxiety in the mathematics classroom, Skinner observed that:

> ...the figure and symbols of mathematics have become standard emotional stimuli. The glimpse of a column of figures, not to say an algebraic symbol or an integral sign is likely to set off not mathematical behavior but a reaction of anxiety, guilt, or fear. (115)

The hypothesis that anxiety is a deterrent to achievement has also been supported by Chansky (116), Keller and Rowley (117), Dreger and Aiken (118), and Keys and Whiteside (119). Symonds, after reviewing selected empirical studies concerning the relationship between anxiety and achievement, stated that anxiety "...will interfere increasingly with problem solving, reflective thinking and creativeness." (120) Learner anxiety is reduced by the democratic environment.

Size of the learning group also bears upon learner anxiety. One implication in the research by Mills (121) and Bales and Borgatta (122) is that four-member groups would be more desirable than three member groups. Their findings suggest that in groups of three members, a coalition of two against one emerges; in groups with more than four members, a leader emerges. Monad and dyad groups were not chosen for several reasons: (a) Slater (123) has shown that levels of tension are increased in dyads as opposed to larger groups and (b) it is unlikely that a single individual would be able to construct solutions to the problems stated in the skeletal hierarchy. From these findings, the model calls for students grouped in fours.

Summary: The findings suggest there is a lack of commonality between the first editions of instructor-generated learning hierarchies and first editions of student-generated learning hierarchies. Moreover, the reported research implies that the meaningfulness of instructional material may be increased by allowing the learner to indicate what gaps exist for him at the time they appear, and then make available appropriate instructional activities.

Interpretation of the relative effectiveness of student-generated learning hierarchies is unclear. Comparisons of results obtained from arm-chaired learning hierarchies, student-generated hierarchies, and learning hierarchies constructed by following the Davidson-Eisenberg-McKeen procedure have not been made. At least no such investigations under controlled experimental conditions were uncovered by the literature search. Until the effect of each of these sequencing procedures upon responding variables such as acquisition, rate of acquisition, forgetting, and rate of forgetting are better known, such research efforts deserve a high priority on the list of needed activity.

Part Two, Research About Learning Hierarchies

Much of the research on learning hierarchies has focused upon the examination of the cumulative learning characteristics hypothesized for such sequences. Relationships between two adjacent levels of a learning hierarchy has received the most attention.

Hypothesized dependency between a set of subordinate behaviors and a terminal behavior draws heavily upon the concepts of mediated transfer and learning sets. Harlow (124, 125) formulated the concept of learning-set to refer to the phenomenon of transfer between several examples from a single class of problems. Gagné and Paradise (126) expanded upon Harlow's meaning and used learning set to refer to specific sets of capabilities, subordinate to some terminal learning task.

A number of studies pertaining to the construction and testing of behavioral hierarchies have been conducted by the University of Maryland Mathematics Project in conjunction with Robert Gagné. In the first of these studies, reported by Gagné and Paradise, the investigators analyzed a final behavior represented by constructing solutions to linear algebraic equations. (126) A learning hierarchy was constructed by a task analysis procedure. The procedure identified three immediate subordinate behaviors. The analysis was then repeated on each of the three subordinate behaviors and yielded a collection of behaviors subordinate to each of the three. Successive iterations produced a learning hierarchy of twenty-two behaviors subordinate to the terminal behavior and arranged into five levels. The study by Gagné and Paradise was designed to test the hypothesis that the acquisition of a terminal behavior depends upon the attainment of a hierarchy of subordinate behaviors which mediate positive transfer from one behavior to the next higher relevant behavior in the learning hierarchy and eventually to the terminal behavior.

The instructional materials consisted of an existing learning program constructed to teach solving of linear equations and was divided into eight booklets designed to be used in eight successive school days. While the derivation of the learning hierarchy was guided by the approach used in the learning program, the hierarchy was not directly defined by the learning program.

Three performance measures were constructed and administered at the completion of the learning program. The first test consisted of constructing solutions to ten equations like those in the learning program. The second measure was a transfer test consisting of ten additional linear equations with unfamiliar forms and symbols. The third test measured the attainment of each of the twenty-two behaviors in the learning hierarchy.

The experimental subjects were sampled from four seventh-grade mathematics classes in two schools. Data are presented for 118 subjects. On the day following the completion of the learning program, the performance measure was administered for twenty-five minutes followed by the transfer measure for twenty minutes. The twenty-two item test assessing the acquisition of the behaviors in the learning hierarchy was administered for fifty minutes the next day.

The ratios of positive transfer (validity estimates) range from 1.00 to a low value of 0.91. Since the values of these ratios were very close to the theoretical prediction and well above the level of chance, it was concluded that the data supported the prediction of instances of positive transfer to each behavior from the subordinate relevant behaviors.

The hypothesis of the Gagné and Paradise study was also investigated with different instructional materials in a later study. Gagné, Mayor, Garstens, and Paradise (127) reported a study designed to test the hypothesis that a final behavior of adding integers depended upon the attainment of a hierarchy of subordinate behaviors. A second purpose of the experiment was to investigate the variables of recallability of relevant subordinate behaviors and effective integration of the subordinate behaviors into the solution of a new behavior. The integration variable was studied by systematically varying the amount of guidance provided to the learner in leading him from one behavior to another. Repetition of previously developed behaviors was used to study the effects of the recallability of subordinate relevant behaviors.

The instructional materials were developed around two terminal behaviors; "adding integers" and "formulating a definition of addition of integers for specific numbers using the necessary properties." Analysis of the two terminal behaviors yielded a hierarchy consisting of fourteen behaviors at six levels. A learning program was written to help the learner acquire behaviors and ordered into a sequence which would follow the learning hierarchy. The program was modified in four specific ways to include different combinations of high and low amounts of repetition and guidance.

One hundred thirty-two students in four seventh-grade classes from two schools comprised the experimental subjects. Each class was divided into "high" and "low" ability groups on the basis of mathematics grades received in a portion of the previous school year. Within each ability subgroup, equal numbers of students were randomly assigned to the four experimental groups: high guidance-high repetition; high guidance-low repetition; and low guidance-low repetition.

The four learning programs corresponding to the four different treatment groups were divided into four booklets and administered on four different days. Each subject received a booklet coded for the particular experimental condition to which he was assigned.

A performance test on addition of integers and a transfer test were given on the two consecutive days following the completion of the learning program. On the third test day the students were given an achievement test that contained at least two items for each of the behaviors listed in the hierarchy. An individual could receive a pass score for a behavior provided he correctly responded to both the items measuring the attainment of that behavior. If the student correctly responded to only one of the items it was counted as a failure.

Examination of the four possible outcomes for relevant higher-lower level performances in this study revealed results in complete accord with the findings of Gagné and Paradise. The ratios of positive transfer (validity estimate) exhibited a range of 0.97 to 1.00. The results of this experiment provide additional support for the conclusion that acquisition of each behavior in a hierarchy is dependent upon the previous mastery of the subordinate relevant behaviors.

A third study by Gagné and others continued and the experiments concerning the sequencing of knowledge as part of an investigation concerned with the manipulation of "repetitiveness" and "temporal spacing" of the hierarchy behaviors. (128, 129) As in the previous studies, the initial step consisted of defining final behaviors and using the analysis procedure described previously to identify a hierarchy of subordinate capabilities. Behaviors from non-metric geometry constituted the final behaviors for this investigation and the analysis yielded nineteen behaviors ordered into six levels subordinate to the final behavior.

The study was designed to investigate two hypotheses: (1) the attainment of each behavior in the hierarchy is dependent upon positive transfer of training from the next lower level capabilities, and (2) such transfer required high recallability of all the next lower subordinate tasks. The manipulative variables were the amount of variety in program examples used to provide practice on each of the subordinate behaviors and the interval of time introduced between the attainment of a behavior and the introduction of the next behavior.

The instructional materials consisted of five different forms of a learning program written and sequenced on the basis of the hierarchy. Program E1 contained only examples similar to the original behavior examples and was designated the minimal variety program. Program E2 incorporated examples of the type used in E1 as well as some examples of intermediate difference in context; E2 was denoted as the intermediate variety program. The maximum variety program, Program E3, contained some E1 and E2 examples plus some which were of maximal contextual difference. Program EA contained irrelevant arithmetic exercises so that the subjects spent the same amount of time as in Programs E1, E2, and E3. Program EO was the basic program with no additional frames beyond the initial frames requiring the completion of each subordinate task.

The population consisted of 116 sixth-grade students in four classes from two schools. The subjects in each class were randomly assigned to one of the five groups represented by the five experimental conditions. The decision to eliminate students absent for one or more sessions resulted in a total of ninety subjects with eighteen subjects in each group. No significant differences were found among the groups on the basis of their mathematics grades for the term prior to the time of experimentation.

Two performance tests were administered on the two days following the completion of the eleven booklets of the learning program (eight for EO). The first test contained a variety of examples representing the class of performances associated with the final task. On the subsequent class day a test of the subordinate tasks was administered to the students.

Comparison of the means of the performance measures reflecting the effects of number and variety of task examples and the elapsed time between task learning revealed no significant differences. The investigators concluded that the variables of task variety and time were not shown to have any effect on learning in this situation.

The importance of order of acquiring subordinate behaviors in a learning hierarchy was again shown to be an important factor in mathematics learning. As in the previous studies, the positive transfer ratios (validity estimates) were approximately one, ranging from 0.95 to 1.00. The data supported the conclusions of the preceding studies, namely, the attainment of any behavior in a learning hierarchy depends upon the achievement of the relevant supporting behaviors.

A retention study was conducted with the same group of subjects approximately nine weeks after the completion of instruction. Tests were administered to measure the retention of the final behaviors and the subordinate behaviors. Each item on the original tests was changed contextually for use on the retention tests to prevent recognition.

Retention as measured by the test on the final behaviors was generally higher than achievement immediately following instruction. The retention ratio (retention score divided by post-test score) was greater than one for every group except E1 where the ratio was 0.75. The mean of E1 differed signficantly from the mean of E0 at the one percent level, but all other individual comparisons indicated no significant differences. On the basis of these results, it was concluded that material of this nature learned by a carefully prepared learning program is highly resistant to forgetting.

An analysis of variance applied to the scores of the five groups on the retention test of the subordinate behaviors revealed no significant differences among the groups. Thus the low retention scores of group E1 on the final behaviors occurred despite the fact that this group retained the subordinate behaviors as well as the other experimental groups. In addition, the retention ratios for this test were quite low compared to the same ratios on the test of the final behaviors. The retention ratios exhibited a range from 0.60 to 0.88. These results indicated that some of the subordinate behaviors were forgotten even though the performance of the final behaviors remained at a level as high as that originally attained.

The forgetting of the subordinate behaviors exhibited an irregular and apparent random pattern; occurring with no greater frequency at one level than another in the hierarchy. It was the opinion of the authors that while the retention of the subordinate behaviors did not appear to be essential to the exhibition of the final behaviors once they had been learned, if the student were required to acquire a new behavior dependent upon the same subordinate behaviors, these same subordinate behaviors would have to be recalled in order to perform their building-block function found in the previous studies.

In each of the studies by Gagné and his co-workers, a hierarchy was constructed by an a priori analysis procedure that was hypothesized to exhibit a pattern of positive transfer to each higher level task from the relevant lower level tasks. The basic data pertaining to this hypothesis consisted of the relative frequency of the pass-fail patterns of the relevant higher-lower performances. Analysis of the data in each of the studies supported the hypothesis of positive transfer.

The University of Maryland Mathematics Project staff (130) continued the line of hierarchy investigations with the analysis of an extensive learning hierarchy on arithmetic operations. The learning hierarchy on algorithms was constructed about three hypotheses of learning dependency:

1) Constructing an explanation of the algorithm with physical situations for a given operation and number system

- Constructing an explanation of the algorithm with physical situations for a given operation and number system different from the one named in the terminal behavior
- Demonstrating the algorithms named in the terminal behavior

2) Constructing an explanation of the algorithm with field properties for a given operation and number system

- Constructing an explantion of the algorithm with field properties for a given operation and number system different from the one named in the terminal behavior
- Demonstrating the algorithms named in the terminal behavior

3)

Demonstrating an algorithm for a given operation and number system

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Demonstrating an algorithm for a given operation and number system different from the terminal objective

Conventional task analysis was not employed in generating the learning hierarchy. Rather an ordering of clusters of the three hypotheses of learning dependency were structured by number systems moving downward from rational numbers, to integers, and then to whole numbers.

Forty-four hypotheses of learning dependency were identified for the algorithms hierarchy. Of the 17 hypotheses rejected by the data, 12 are tests of the same three behaviors -- constructing an explanation with field properties as the terminal behavior of the hypothesis, demonstrating how to perform the algorithm and constructing explanations with properties of an earlier algorithm. A more detailed examination of these data reveals subjects able to exhibit two subordinate behaviors are not able to exhibit the terminal constructing behaviors. The pattern appears each time the instructional material moved from one number system to another as well as those times when the instructional material moved from the operation of addition or subtraction to multiplication or division within the same number system. Similar difficulty was not observed in the acquisition of the "constructing explanations with physical situations" behavior.

Cook (67) reported an investigation in which knowledge of the learning hierarchy was included as one information treatment among several. One treatment group was informed of the behavioral objectives for each lesson, another treatment group was informed of the behavioral objectives for each lesson and the learning hierarchy into which the behaviors were sequenced, a treatment group was informed of the learning hierarchy, and a control treatment with no knowledge of objectives or learning hierarchy. Cook's findings show no differences in achievement on an immediate posttest among the four treatment groups. A significant effect for the treatment group informed about the behavioral objectives was reported for a retention measure. A similar effect did not appear for the behavioral objectives and learning hierarchy or the learning hierarchy alone treatment groups. Cook's findings suggest the conjecture that "knowledge of the learning hierarchy" interferes with the "resistence to forgetting" effect observed in the "knowledge of behavioral objective" studies.

Eisenberg (106) and McKeen (107) have investigated the conjecture that a learning hierarchy constructed by student input according to the Davidson-Eisenberg-McKeen procedures will obtain a validity estimate of 0.85 or higher on its first formulation. Their findings do not support the conjecture. As part of these same investigations they also reported a larger number of **hypotheses** of learning dependency being rejected (below the 0.85 level) for students with low past achievement scores than for students with high past achievement scores. Sixteen percent of the hypotheses of learning dependency were rejected for the high group, while 34% were rejected for the low group. Shriner and Seidl followed up on the high and low group variance observed by Eisenberg and McKeen.

Several researchers have attempted to investigate the relationship of guidance and ability to learning hierarchies constructed by students. Shriner (131) and Seidl (132) for example, investigated the questions of whether students of different ability levels (1) generate different learning sequences, (2) require different amounts of guidance, and (3) require different amounts of time.

Twenty-four early childhood-elementary majors at the University of Maryland were the subjects of their studies. On the basis of past achievement determined by their college cumulative grade point average and their high school percentile rank, twelve of the students were selected as high ability students and twelve as low ability students. Each set of twelve students was randomly divided into three instructional groups of four students each. By means of the Modified Small Group-Discovery Method, of Davidson (105) each group was presented the same broadly stated problems concerning the algebraic structure of sets of 2-by-2 matrices. The students attempted to solve the problems as far as possible by themselves. The instructor gave hints or initiators to the students in the form of suggestions, questions, or examples to work. A daily record of the student activities in each instructional session indicated the behaviors identified by the students as prerequisite to attain the solution to the broadly stated problems. These behaviors were arranged by the investigators to form two student-generated learning sequences, one for the high ability groups and the other for the low ability groups. Tallies of the number of initiators and the number of fifteen-minute intervals each instructional group required to solve all four of the broadly stated problems provided data relative to the amount of guidance and the amount of time.

The conclusions of their investigations were the following: (1) no differences were found between the learning sequences generated by the high and low ability groups; (2) the low ability groups required greater amounts of guidance and (3) the low ability groups required greater amounts of time to solve the proposed problems.

Gagné (47) has offered the conjecture that the ordering of capabilities within a learning hierarchy proceeds from simple responses which are subordinate to verbal or nonverbal chains, which in turn are subordinate to concepts, which in turn are subordinate to principles, which in turn are subordinate to an independently generating knowledge capability.

Payton (133) investigated the Gagné conjecture concerning the ordering of conditions within a learning hierarchy. The terminal objective was concerned with that portion of an above-knee prosthetic checkout which deals with the evaluation of static fit and alignment. A hierarchy was constructed by task analysis. Each level within the hierarchy was then identified with one of the levels in Gagné's conditions of learning, the conditions are stimulus-response, verbal chains, multiple discriminations, concepts, principles, and problem solving. A validation panel of ten experts was formed who corrected and approved the hierarchy which had been constructed. The panel also approved two teaching-learning tasks and two evaluation tools for each cell in the hierarchy.

Using the materials thus prepared, the hierarchy was followed from the bottom level of stimulus-responses to the terminal objective in the spring of 1970, and the results of the instruction evaluated. Hypotheses of consistency and adequacy, and inverse consistency and inverse adequacy were defined, and these hypotheses were used to evaluate the results of the instructional sequence. A predetermined level of eighty per cent achievement had been specified as an acceptable level for the validity estimate conditions of learning for this project. In the spring of 1970 the hypotheses of learning dependency were supported at the 0.80 level for the lower two levels of the hierarchy. Therefore the hypothesisof Payton's study was not supported by the data collected in 1970.

Based upon the data collected in 1970, revisions were made in the teaching and evaluation plans. The second data collection was made in the spring of 1971. The decisions to accept or reject the hypotheses of learning dependency were made on the basis of the consistency and adequacy ratios. Based upon the data collected in 1971, Payton concludes that achievement at each level of the hierarchy did mediate to achievement at the next level in the hierarchy from the lowest level up to and including problem solving. The hypothesized ordering of the conditions of learning were validated from the lowest level up to the terminal objective, but the last step to the terminal objective was not.

Another direction of research on learning hierarchies is the relationship between two or more content areas and two or more learning hierarchies. Kolb (134) investigated the question of whether connecting a learning hierarchy from one content area to a learning hierarchy in a second content area would facilitate learning when the first hierarchy contains behaviors subordinate to those in the second hierarchy. Such a situation is commonly encountered in science when certain mathematical behaviors are prerequisite. The usual content arrangement is to segregate mathematics and science. Kolb selected three terminal behaviors from an exercise in Science - A Process Approach, an experimental elementary science curriculum produced by the American Association for the Advancement of Science Commission on Science Education.

By means of the task analysis a hierarchy was constructed which included three terminal behavior tasks and twenty-six relevant subordinate mathematical behaviors. This hierarchy was used as a guide for developing the instructional sequence in mathematics which was related to the science exercises.

Two tests were constructed. Measure I was designed to test the acquisition of each of the twenty-six behaviors in the mathematics hierarchy and Measure II assessed the acquisition of the behaviors stated as objectives in the two science exercises. The two tests were used both as pretests and posttests.

The time allotment consisted of a two-day testing period prior to the learning sequence, a fourteen-day learning sequence in mathematics, one day to administer Measure I, a six-day instruction period in science followed by the administration of Measure II.

Subjects for the experiment were 275 pupils enrolled in eight fifth grade classes. Students within each class were randomly assigned to one of two treatments. During the learning sequence, those students assigned to treatment A were taught the mathematics that occurred in their books at the time. The students in treatment B, however, were taught by means of the learning sequence that was based on the mathematics hierarchy. The final tasks included in the hierarchy were considered necessary for the quantitative science behaviors. Each teacher taught both of the treatments within her class by meeting with each group on alternate days.

On the basis of the tests administered, Kolb found no significant differences existed between the two treatments on the pretests. Significant differences in favor of treatment B at the 0.01 level of confidence were found on the posttests.

He concluded that the instructional sequence in mathematics related to the science exercises facilitated the acquisition of the quantitative science behaviors.

Gray (135) continued this same research direction. He compared the effectiveness of two learning sequences in facilitating the acquisition and retention of certain mathematics and science behaviors. In one learning hierarchy, the related material of mathematics and science were integrated; in the second sequence they were not. Gray identified twenty-two objectives in a structured hierarchy as prerequisite for three terminal behaviors. This hierarchy was used as a guide in the construction of the learning sequences. He concluded that the integrated hierarchy was superior to the non-integrated sequence in facilitating acquisition of the mathematics behaviors. The two sequences did not have differential effects on the rate of forgetting of the mathematics or science behaviors.

<u>Summary</u>: The principle of a learning hierarchy reduces itself to the principle of positive transfer where mediation from one level to another is provided by instructional activities. Gagne's position that the transfer is occurring among learned capabilities does seem to be supported by the literature. Whether these learned capabilities organize themselves by complexity according to the Gagné conditions is as yet unclear. The existence of the positive transfer appears to be unaffected by shifts between disciplines. The investigations of both Kolb and Gray support this contention.

Relationships among levels within a learning hierarchy are less clear. The hypotheses that the strength of dependency decreases as the number of intervening levels increases does find some support. However, the inability of several researchers to obtain validity estimates above 0.80 after several learning hierarchy revisions raises many questions about the completeness of the psychological analysis represented by a learning hierarchy.

The generalizability of one set of subordinate behaviors to mediate to a terminal behavior with efficiency is brought into question by the studies on learner generated vs expert generated learning hierarchies. It now appears reasonable to conjecture that the learning hierarchy generated by a single student in a four member group will be as effective in leading each student to the acquisition of a given terminal behavior as is a concensus hierarchy developed by "experts" in the field. In addition, the literature also suggests the research hypothesis that the lower the ability of the learner, the greater the number of subordinate behaviors necessary to achieve positive transfer to the terminal behavior. This relationship also appears to hold for each hypothesis of learning dependency within a learning hierarchy.

Part Three, The Psychometrics of Learning Hierarchies

Obtaining a validity estimate for a learning hierarchy currently involves obtaining estimates of the magnitude of positive t nsfer for each hypothesis of learning dependency within the hierarchy and requiring a preestablished lower bound for the validity estimate on all learning dependencies. If one or more hypotheses of learning dependency fail to meet the minimum validity level, then a revision is made and data are collected again. Cox and Graham (136) as well as Walbesser (137) have reported on this revision procedure:

Tryout data is designed to yield information about each hypothesis of learning dependency as to whether particular behaviors transfer positively to another behavior, whether the behaviors are independent, or whether they alternate in their transfer effects. Procedures for Obtaining Validity Estimates: Several procedures have been advanced for obtaining validity estimates on learning hierarchies. Gagnè adopted one procedure of examining the validity of learning hierarchies, several research workers have employed a scaling procedure advanced by Guttman. (138) The Commission on Science Education of the American Associatic for the Advancement of Science obtained validity estimates on eight science process hierarchies by employing a modification of Gagné's procedure. (139) Still another variant on this procedure has been advanced by Walbesser and Eisenberg (140).

In the learning hierarchy research reported by Gagné, the validity estimates are reported in terms of the one ratio of positive transfer between lower relevant behaviors and a higher level behavior. (126) The prediction of high positive transfer from a given learning set to one at a higher level is tested by noting the pattern of pass and fail which was obtained between lower and higher adjacent sets throughout the hierarchy. If a given behavior has two or more behaviors subordinate to it, then the theory requires that all of the subordinate behaviors be passed before completion of the given behavior is possible.

The four possible empirical relationships for passing and failing relevant higher-lower behavior combinations and their implications are:

1. (Higher 1, Lower 1). This indicates successful acquisition of all relevant subordinate behaviors and positive transfer to an adjacent higher behavior.
2. (Higher 1, Lower 0). This indicates successful acquisition of higher level behavior and failure to acquire one or more of the relevant subordinate behaviors.
3. (Higher 0, Lower 0). This indicates failure to acquire the higher level behavior after failure to acquire all of the relevant subordinate behaviors.
4. (Higher 0, Lower 1). This indicates inability to exhibit a higher level behavior after acquisition of all relevant subordinate behaviors.

These four relationships are expressed symbolically as (1,1); (1,0); (0,0); and (0,1). Of the four relationships, only (1,0), which indicates acquisition of a given behavior after failure in subordinate relevant behaviors, contradicts the theory. The ratio of pass-fail patterns which support the theory is obtained by dividing the number of instances consistent with the hypothesis of positive transfer, [(1,1) and (0,0)] by the total testable instances, that is, [(1,1), (0,0), and (1,0)]. The theoretical prediction for each ratio computed by the preceding formula for each pass-fail relationship is 1.00.

A second procedure for obtaining validity estimates was proposed by the Commission on Science Education of the A.A.A.S. (139) The same four fold table is employed as with the single ratio test. However, three ratios are computed: consistency, adequacy, and completeness.

This procedure suggests that the numerator of the ratio measuring consistency contains only the total instances which support positive transfer, that is (1,1). While it can be said that (0,0) is consistent with the theory, it is certainly not an indication of positive transfer. The inadmissability of the instances of (0,0) has the effect of lowering the ratio achieved. If the ratio agreed upon as acceptable is 0.90, then the number of supportive instances must be greater to attain this level than if the ratio could include instances that were merely consistent with the theory.

Consistency is considered a necessary, but not sufficient, condition for a valid hierarchy. Consideration must be given to two other factors not treated previously before validation is completed. One of these factors refers to the adequacy of the hierarchy and the other refers to the completeness of the hierarchy.

The adequacy of a hierarchy requires an examination of how often the learner has achieved a behavior after relevant subordinate behaviors have been attained. If the instruction is adequate, then a learner who has attained the subordinate behaviors will be able to progress to the behavior that employs these as subordinates. The adequacy ratio is defined as the quotient of the number of (1,0) divided by [(1,1) and (0,1)]. The level of acceptability for the ratio is 0.90.

High consistency and adequacy ratios are necessary, but not sufficient conditions for claiming validity for the hypothesis of a learning hierarchy. This is postulated because high consistency and adequacy ratios can be attained which involve only a small number of the actual subjects tested. When most of the subjects do not acquire the terminal behavior and do not acquire at least some of the subordinate behaviors, this occurs. These cases will fall into the (0,0) category. Large numbers of cases in the (0,0) category are viewed as evidence of incomplete instruction. The completeness ratio is defined as the quotient of (1,1) divided by [(1,1) and (0,0)]. The level of acceptability is 0.90.

An illustrative investigation which uses this procedure for obtaining validity estimates reports data on a hierarchy concerned with the terminal behavior of "describing spatial arrangements". (141) The use of this procedure was also reported on a nine level, 17 behavior learning hierarchy on classifying. (137) Another example of the use of this paradigm is the research conducted by the Wisconsin Research and Development Center for Cognative Learning entitled "A Study of Parts of the Development of a Unit of Probability and Statistics for the Elementary School". (142)

A third procedure, also a variant of the four fold table suggested by Gagné, is the Walbesser-Eisenberg validation criteria. (140) These researchers have developed a numerical procedure for testing a hypothesis of "task dependency" in a learning hierarchy. Their procedure provides a numerical criterion for determining the validity estimates of a hierarchically organized learning sequence.

1. Consistency Ratio. If after instruction the student has acquired the terminal behavior of the hypothesis, then it is hypothesized that he will have also acquired all subordinate behaviors. Quantitatively, the consistency implication of a hierarchy is defined to be the ratio of the frequency of the (1,1) instances for the hypothesis divided by the sum of the frequencies the (1,1) and (1,0) instances for the hypothesis. This ratio ranges from 0 to 1 provided that the frequencies of the (1,1) and (0,1) instances are not both zero. In the case where both cells are few the ratio is not applicable. The consistency implication says acquisition of the terminal behavior implies acquisition of all subordinate behaviors.

2. Adequacy Ratio. If the student has acquired all subordinate behaviors, then it is hypothesized that he will be capable of performing the terminal behavior of the hypothesis provided that he has been given mediating instruction. Numerically the adequacy of a hypothesis in a learning hierarchy is defined to be the ratio of the frequency of the (1,1) instances for that hypothesis divided by the sum of the frequencies of the (1,1) and (0,1) instances for the hypothesis. This ratio also ranges from 0 to 1, provided that the set of (0,1) and (1,1) responses is not empty. The adequacy hypothesis tests the implication that acquisition of all subordinate behaviors implies, with instruction, acquisition of the terminal behavior.

3. Inverse Consistency Ratio. The inverse consistency ratio tests the implication that nonacquisition of the terminal behavior implies nonacquisition of one or more of the subordinate behaviors. Hence, it is defined to be the ratio of the frequency of the (0,0) instances for the hypothesis. Provided that the set of responses for the (0,0) and (0,1) categories is nonempty, this ratio also ranges from 0 to 1.

4. Inverse Adequacy Ratio. The inverse adequacy ratio tests the implication that nonacquisition of all subordinate behaviors, even with mediating instruction, implies nonacquisition of the terminal behavior. Inverse adequacy is defined to be the ratio of the frequency of the (0,0) ordered pair for the hypothesis divided by the sum of the frequencies of the (0,0) and (1,0) instances for the hypothesis. Provided that the frequencies for (0,0) and (1,0) categories are not both zero, this ratio ranges from 0 to 1.

5. Completeness Ratio. In an effort to determine the strength of a hypothesis of task dependency a completeness ratio is defined. The completeness ratio for a hypothesis of task dependency in the hierarchy is defined to be the ratio of the frequency of the (1,1) instances for the hypothesis divided by the sum of the frequencies of the (1,1) of the (1,1) and (0,0) instances for the hypothesis. This ratio estimates the percentage of individuals capable of traversing the hypothesis as opposed to those incapable of performing at least one of the subordinate cells in the hypothesis.

An adequacy ratio, completeness ratio, inverse adequacy ratio, inverse completeness ratio, and a completeness ratio are associated with each hypothesis in the learning hierarchy. A learning hierarchy is considered valid if, and only if, an adequacy, consistency, and completeness ratio of at least 0.85 is obtained for each hypothesis in the learning sequence.

Eisenberg's application of this procedure is contained in his dissertation entitled "The Integration of Modified Learner-Generated Sequences into the Development of a Behaviorally Stated Learning Hierarchy as Applied in Mathematics Curricula Construction". (106) Another example of the application of this procedure is found in McKeen's dissertation, "A Model for Curriculum Construction Through Observations of Students Solving Problems in Small Instructional Groups". (107)

Some investigators have applied to data of this sort the method suggested by Guttman for scaling qualitative data, including a statistic called the reproducibility coefficient. (143) However, Guttman's method does not provide an analysis as discriminating as that described by Gagné or Walbesser and Eisenberg whenever the sequence is not linear. Another weakness of the Guttman procedure is that it does not provide a means of distinguishing between a subordinate relationship and a coordinate one.

Wang reported validity estimates for a learning hierarchy on counting and numeration using the Guttman reproducibility coefficient. (144) An interesting observation on the lower bound of reproducibility coefficients is contained in a paper by Jay M. Jackson of McGill University entitled, "A Simple and More Rigorous Technique of Scale Analysis". (145) Further limitations on the use of this statistic in obtaining learning hierarchy validity estimates is contributed by Carrol. (146) He observed that one serious limitation of the Guttman scaling procedure is with respect to its only being applicable to linear sequences. Most hypothesis of learning dependency are not linear relationships.

Eisenberg and Walbesser offer two important additional tools in the description of learning hierarchies: the magnitude and complexity. (140) They suggest that if there exist two equally valid learning hierarchies each designed to achieve the same terminal behavior, an obvious consideration would be one of time efficacy. Which hierarchy can be traversed in the least amount of time? One well established individual difference is that each learner can be expected to traverse a learning hierarchy at a unique time rate. An "average traversing time" for the population with which the hierarchy was validated could be associated with each learning hierarchy. But the generalizability of such a statistic is questionable. A more reasoned comparative measure for hierarchies is to consider the complexity of the structure itself.

For each hypothesis of task dependency, the number of subordinate behaviors may be considered the "complexity of the hypothesis". Let N equal the number of hypotheses in the learning structure. Therefore, for any learning hierarchy, a complexity coefficient, designated cc, can be computed.

$$\text{Complexity coefficient} = cc = \frac{\sum_{i=1}^{N} \text{complexity of hypothesis (i)}}{N}$$

The complexity coefficient denotes an average number of subordinate behaviors for each hypothesis in the hierarchy.

Another consideration of the structure of a learning sequence raised by Eisenberg is the number of subordinate levels--that is, the length "L" of the hierarchy.

With these measures it is possible to associate with each learning hierarchy a vector in which the first component of the vector is N, the second component is cc, and the third component is L. A learning hierarchy that is associated with the vector (N_1, cc_1, L_1) is then said to be of "higher magnitude" than a learning hierarchy associated with the vector (N_2, cc_2, L_2) if two of the following are strict inequalities: $N_1 \neq N_2$, $cc_1 \neq cc_2$, or $L_1 \neq L_2$. Given two learning hierarchies with essentially equal validity estimates, the one of lesser magnitude is the more desirable. Hence, these two new measures provide a means of choosing among learning hierarchies with the same terminal behaviors.

Item and Measure Statistics. Tests associated with learning hierarchies and behavioral objectives are generally criterion referenced measures rather than norm referenced measures. The item and measure statistics associated with norm referenced measures are extensive and well known by most educational researchers. Criterion referenced item and measure statistics are few in number, although there is extensive activity currently in this field.

Popham and Husek (147) provided a general overview of criterion referenced measures and their potential effect upon educational measurement. Ward (148) has also written an excellent expository piece on such measurement.

Harke's (149)work on hierarchy analysis with the use of multiple choice test items offers an interesting variation to the individual testing or constructed responses format used by many criterion referenced measures. His data analysis procedure draws heavily from the pattern analysis work of Remoldi and Grib (150). Pattern analysis of multiple choice test items appears to offer one solution to the underestimating problem raised by Walbesser and Carter (76) in this study of individual versus group testing.

A technique for estimating the reliability of criterion referenced tests has recently been described by Livingston (151). The formula which Livingston suggests to provide a reliability estimate based upon the split-half test is:

$$k^2(X,T_X) = \frac{P^2(X,T_X)\ J^2(X) + (M_X - C_X)^2}{J^2(X) + (M_X - C_X)^2}$$

where $P^2(X,T_X)$ is the norm-referenced reliability coefficient, $J^2(X)$ is the variance, M_X is the mean and C_X is the criterion score.

This reliability estimate is then adjusted for the entire test using a formula which is a version of the Spearman-Brown formula adjusted to criterion referenced tests:

$$\text{reliability} = \frac{nk^2(X,T_X)}{1 + (n-1)k^2(X,T_X)}$$

where n is the number of times the length of the test is to be increased.

The reliability estimates obtained through the application of these formulas tend to be high, with a lower bound at the mean of the criterion measure.

<u>Summary</u>: The investigation of learning hierarchies concern themselves with questions of positive transfer. Data analysis procedures first focused upon assessing the magnitude of positive transfer for one "hypothesis of learning dependency", that is, one set of subordinate behaviors mediating to exactly one terminal behaviors. Strings of hypotheses of learning dependencies or "learning hierarchies" were then investigated for sequestial or cumulative learning effects.

Four procedures are currently available for learning hierarchy analysis: Guttman scale, Gagné, AAAS Commission on Science Education, and Walbesser-Eisenberg.

Item and measure statistics for criterion referenced tests are rare. One reliability estimating procedure is available. How many criterion items to sample for estimating the acquisition of a given behavior is not known. The effect of increasing the number of assessment tasks for a given behavior upon decisions of presence or absence are not known. The effects of changing performance tasks to paper and pencil tasks are not known. Much work still needs to be done before any clear direction is apparent for the item and measure statistics associated with learning hierarchies and behavioral objectives.

Research on learning hierarchies may also be summarized in terms of hypotheses supported. Such a summary follows.

I. Research Hypothesis: The acquisition of a terminal behavior depends upon the attainment of a hierarchy of subordinate behaviors that mediate positive transfer from one set of behaviors to the next higher relevant behaviors in the sequence and eventually to the terminal behavior.

A. When the positive transfer must achieve a 0.75 level.

Research Supporting the Hypothesis	Research Not Supporting the Hypothesis
Gagne and Brown 96	
Gagne and Paradise 126	
Gagne, Mayor, Garstens, and Paradise 127	
Gagne and the U.M.Ma.P. Staff 128	
Gagne and Bassler 129	
U.M.Ma.P. Staff 130	
Donald F. Shriver 131	
Neil W. Seidl 132	
Otto D. Payton 133	
John R. Kolb 134	
William L. Gray 135	
Cox and Graham 136	
Henry H. Walbesser 137	
Diana K. Hestwood 141	
The University of Wisconsin R & D Center for Cognitive Learning 142	
J. Marvin Cook 67	
Ronald L. McKeen 107	
Theodore A. Eisenberg 106	
Carol Van de Ree Dutton 153	
John R. Shannon 103	
Thomas E. Rowan 61	

B. When the positive transfer must achieve a 0.90 level.

Research Supporting the Hypothesis	Research Not Supporting the Hypothesis
Gagne and Brown 96	U.M.Ma.P. Staff 130
Gagne and Paradise 126	Donald F. Shriver 131

Research Supporting
the Hypothesis (Cont.)

Gagne, Mayor, Garstens, and Paradise 127

Gagne and the U.M.Ma.P. Staff 128

Gagne and Bassler 129

Henry H. Walbesser 137

Research Not Supporting
the Hypothesis (Cont.)

Neil W. Seidl 132

Otto D. Payton 133

John R. Kolb 134

William L. Gray 135

Cox and Graham 136

Diana K. Hestwood 141

The University of Wisconsin
R & D Center 142

J. Marvin Cook 67

Ronald L. McKeen 107

Theodore A. Eisenberg 106

John R. Shannon 103

Thomas E. Rowan 61

Carol Van de Ree Dutton 153

II. Research Hypothesis: Given the same terminal behavior, the subordinate behaviors included in a student or student-instructor generated learning hierarchy do not correspond to the subordinate behaviors included in an "expert" generated learning hierarchy.

Research Supporting
the Hypothesis

Robert F. Mager 43

Mager and McCann 63

Jerome D. Kaplan 102

John R. Shannon 103

Neil A. Davidson 105

Theordore A. Eisenberg 106

Donald F. Shriver 131

Neil W. Seidl 132

Ronald L. McKeen 107

Research Not Supporting
the Hypothesis

III. Research Hypothesis: The greater the retention of the subordinate behaviors of a learning hierarchy, the greater the probability of retaining the terminal behavior.

Research Supporting the Hypothesis	Research Not Supporting the Hypothesis
	Gagne and U.M.Ma.P. 128
	Gagne and Bassler 129
	Henry H. Walbesser 137

IV. Research Hypothesis: Following a student generated learning hierarchy results in greater acquisition of the terminal ~~behaviors than~~ following an "expert" generated learning hierarchy.

Research Supporting the Hypothesis	Research Not Supporting the Hypothesis
	Robert F. Mager 43
	Mager and McCann 63

V. Research Hypothesis: Following a student generated learning hierarchy increases the rate of acquisition of the terminal behaviors over that achieved by following an "expert" generated learning hierarchy.

Research Supporting the Hypothesis	Research Not Supporting the Hypothesis
Mager and McCann 63	
Allen and MacDonald 100	
Campbell and Chapman 101	

VI. Research Hypothesis: The entry behaviors a student possesses are greater than the behaviors he admits possessing when measured at the beginning of instruction which follows a learning hierarchy.

Research Supporting the Hypothesis	Research Not Supporting the Hypothesis
Slater E. Newman 64	
Robert F. Mager 97	
Mager and Clark 98	
Richard S. Hatch 99	

VII. Research Hypothesis: Increasing the number and variety of tasks increases the probability of acquisition of the terminal behavior.

Research Supporting the Hypothesis	Research Not Supporting the Hypothesis
	Gagne and U.M.Ma.P. Staff 128
	Gagne and Bassler 129

VIII. Research Hypothesis: Increasing the number and variety of tasks increases the rate of acquisition of the terminal behavior.

Research Supporting the Hypothesis	Research Not Supporting the Hypothesis
	Gagne and U.M.Ma.P. 128
	Gagne and Bassler 129

IX. Research Hypothesis: The higher the ability of the learner the smaller the number of subordinate behaviors in a student or student-instructor generated learning hierarchy.

Research Supporting the Hypothesis	Research Not Supporting the Hypothesis
	Donald F. Shriver 131
	Neil W. Seidl 132

X. Research Hypothesis: Integrating behaviors from more than one content discipline facilitates acquisition of the terminal behaviors of a learning hierarchy.

Research Supporting the Hypothesis	Research Not Supporting the Hypothesis
John R. Kolb 134	
William L. Gray 135	
Heather L. Carter 77	

XI. Research Hypothesis: Knowledge of the learning hierarchy increases the probability achievement of each behavior within the hierarchy.

Research Supporting the Hypothesis	Research Not Supporting the Hypothesis
	J. Marvin Cook 67

XII. Research Hypothesis: Knowledge of the learning hierarchy increases the resistance to forgetting for each behavior within the hierarchy.

Research Supporting the Hypothesis	Research Not Supporting the Hypothesis
	J. Marvin Cook 67

XIII. Research Hypothesis: Positive transfer in a learning hierarchy mediates from one Gagne condition to the next at the 0.75 level.

Research Supporting the Hypothesis	Research Not Supporting the Hypothesis
Otto D. Payton 133	

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